WADC TECHNICAL REPORT 52-112

DEVELOPMENT OF FABRICS FOR USAF SUMMER UNIFORMS USING SYNTHETIC FIBERS

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MATERIALS LABORATORY

JULY 1952

WRIGHT AIR DEVELOPMENT CENTER

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July 1952

RDO No. R612-13

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

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Dayton, O. 200, 28 Oct. 52

FOREWORD

This report was prepared by Materials Laboratory, Research Division, Wright Air Development Center, under Research and Development Order No. R612-13, Textile Materials for Air Force Clothing, with the author of the report acting as project engineer. The report deals with the following contracts:

Contract No.	Fabric Designation	Type	Fibers
AF 33(096)51-12678-E	"A"	100%	Wool
AF 33(096)51-12732-E	"B"	100%	Dacron*
AF 33(096)51-12733-E	"C"	55%	Dacron -
		45%	Wool
AF 33(601)52-1070-E	"D"	50%	Dacron -
		50%	Viscose Rayon

The above fabrics were all manufactured to meet the requirements of Specification JAN-C-391, Type I. Allowances were made for variation in the physical characteristics of the different fibers.

*E. I. du Pont de Nemours trade-mark for its polyester fiber, formerly called "Fiber V".

ABSTRACT

This project was undertaken as a result of a letter from Headquarters USAF, dated 29 March 1951, entitled "Conservation of Wool", and because it was believed that synthetic fibers possessed an untapped potential adaptable to the needs of the USAF for uniform purposes.

"Dacron", a polyester fiber, was chosen as the principal constituent in this investigation because of its unusual properties. The manner in which this fiber would react when used in a uniform fabric and when blended with other fibers could not be determined by laboratory methods; hence the service wear test.

This service wear test was conducted during the months of July, August, September and October of the year 1951 at Wright-Patterson Air Force Base, Ohio, by the Textile Branch of the Materials Laboratory, Research Division, Wright Air Development Center, Forty-eight men participated in the test.

The results of this test indicate that Dacron, when blended with wool or viscose rayon in a fifty-to-fifty weight ratio, will produce a fabric superior to either the presently used 100% wool or the experimental 100% Dacron fabric.

PUBLICATION REVIEW

Manuscript Copy of this report has been reviewed and found satisfactory for publication.

FOR THE COMMANDING GENERAL:

M. E. SORTE
Colonel, USAF
Chief, Materials Laboratory
Research Division

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INTRODUCTION

The superiority of some of the newer synthetic fibers in strength and durability makes them excellent candidates for use in USAF uniform fabrics. In addition, the potential wool shortage, in the event of hostilities, and the relative price stability of synthetic fibers make this field one of particular significance for those concerned with uniform materials. With these considerations in mind this investigation was made.

DEVELOPMENT OF FABRICS FOR USAF SUMMER UNIFORMS USING SYNTHETIC FIBERS

I. Procedure

A. Selection of Fibers:

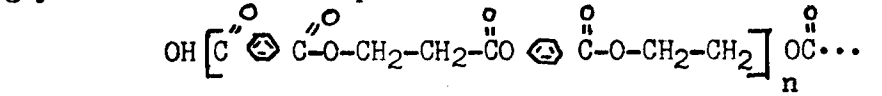
Three fibers were chosen for this investigation. Wool was a logical selection because it has been the standard for military uniforms for many years. Also, it was necessary to have a basis upon which to judge the experimental fibers and wool provided the "yardstick".

Fabrics of 100% rayon have proved unsatisfactory in past tests, but a rayon blend was included in this study because of its relatively low price, nice hand, and comfort. If these properties could be utilized, and such characteristics as ease of wrinkling and poor crease retention could be overcome by blending, viscose rayon would be worthy of consideration. With these facts in mind a rayon-dacron blend was included in the investigation.

Dacron, the other fiber used, was the fiber that helped attract the attention of the USAF to synthetic fibers for clothing purposes. According to E. I. du Pont de Nemours and Company, the Dacron polyester fiber is generally outstanding in the following characteristics:

1) Wrinkle resistance (Wet and Dry)
2) Recovery from Wrinkles (Wet and Dry)
3) Shape retention (Wet and Dry)
4) Stretch resistance (Wet and Dry)
5) Abrasion resistance (Wet or Dry)
6) Fabric texture and dry handle
7) Heat resistance
8) Resistance to weakening by bleaches
9) High flex life
10) Quick drying
11) Strength.

Dacron polymer is formed by the polymerization of the ethylene glycol diester of terephthalic acid. The structure is as follows:



The most predominant advantages of Dacron are wrinkle resistance, crease retention in very humid conditions, and abrasion resistance. These qualities were responsible for the selection of Dacron as the chief fiber for this study.

B. Selection of Fabrics:

Four fabrics were selected for this service wear test. The regulation 100% wool, designated as "A" in this report, was included as a control sample to provide a basis for comparison. The 100% Dacron, designated as "B", was added to provide data on a completely synthetic fabric and to evaluate Dacron as fully as possible. A blend of 55% Dacron and 45% wool, designated as "C", was designed to combine the hand of wool with the crease resistance, strength, and other desirable qualities of Dacron. The fourth fabric, "D", was composed of 50% Dacron and 50% viscose rayon. This fabric is an attempt to combine the desirable qualities of Dacron with the comfort, coolness, and relatively low cost of viscose rayon.

The weave, weight, and other physical characteristics of all four fabrics were based upon Specification No. JAN-C-391, Type I, but do not necessarily conform thereto because of the varying fibers used.

C. Selection of Personnel:

Forty-eight USAF personnel were solicited to take part in the study. Each participant pledged his cooperation in supplying the needed data. The tailoring was done by one company to assure uniformity. Each man was given two uniforms consisting of shirt and trousers.

All participants were engaged in duties under very similar climatic conditions. A daily record of temperature, relative humidity, and precipitation was made. A graph showing these records is included in this report.

D. Distribution of Uniforms:

Each man was given two types of fabric. The materials were put into six groups and in such manner as to provide comparative data for all four fabrics. The following table shows the method of grouping:

Group		FABRICS IN GROUP
I	(A and B)	100% Wool and 100% Dacron
II	(A and C)	100% Wool and 55% Dacron - 45% Wool
III	(A and D)	100% Wool and 50% Dacron - 50% Viscose rayon
IV	(B and C)	100% Dacron and 55% Dacron - 45% Wool
V	(B and D)	100% Dacron and 50% Dacron - 50% Viscose rayon
VI	(C and D)	55% Dacron - 45% Wool and 50% Dacron - 50% Viscose rayon

II. Test Data:

A. Questionnaire:

Questionnaires were provided for the recording of data to assure uniformity of text in the returns. The participants were asked to state how many times each garment was worn, if the wearing was comfortable or uncomfortable, number of times cleaned, pressed and also to answer fifteen questions pertaining to the maintenance and performance characteristics of each fabric.

In order to provide a numerical index which would indicate overall preference of "Acceptability", based on the fifteen questions, a system of weighted ratings was used.

Referring to Table II, the column headings were established as outlined below:

The data from the questionnaire (Table I) were analyzed and it was found that in nine cases differences reported between the fabrics were statistically significant. In the other six cases, no significant differences between fabrics were found. The six questions showing no significant differences were dropped and the remaining nine questions were ranked by laboratory and participating personnel in order of what they considered their relative importance.

These rankings were used to determine a composite ranking which is shown in column (a). The order of preference (b) was determined from the compilation shown in Table I. In those cases where the relative position of a fabric had no significant statistical meaning, the fabric was not listed. In cases where two or more fabrics were not significantly different from each other, they are grouped by parentheses.

The "Weight of question" (e) was an arbitrarily selected system for giving more weight to the more important questions. The "Adjusted preference points" (d) were assigned on the basis of the inverse order of preference, e.g., first choice was assigned 4 points, second choice, three points, etc. In cases where a fabric's relative position was not statistically clear, that fabric was assigned preference points which assumed it to be average in that particular property.

The "Acceptability number" (e) is the product of (c) and (d). The sum of the acceptability numbers for each fabric is designated as its "Acceptability index".

FIG. 1 ENVIRONMENTAL CONDITIONS DURING PERIOD OF TEST

JULY - OCTOBER 1951

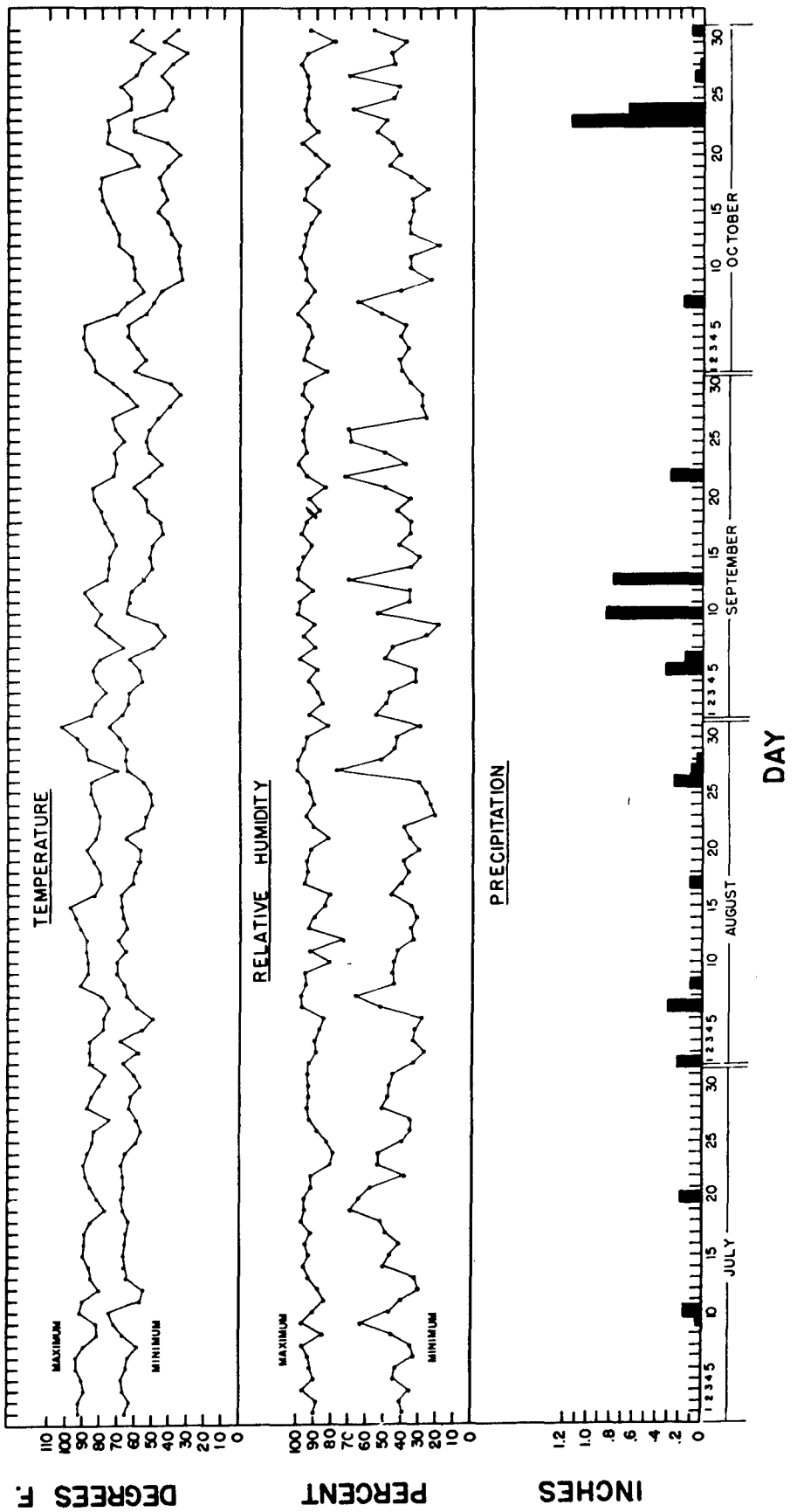


TABLE I

Compilation of Data from Ques

	A -
Reports Evaluated	30
Question	
1. Which of the two uniforms has the better wrinkle resistance?	0
2. Do wrinkles tend to hang out overnight?	0
3. Can you notice any difference in wrinkling in damp and dry weather? Which is worse?	0
4. Did you notice any "bagging" at knees or seat of the uniforms?	0
5. Did you notice any difference in crease retention, wrinkle resistance, or hand after several cleaning and pressing treatments? Explain.	3
6. Did you notice any shrinkage or stretching?	7
7. Did the fabric seem to spot or stain easily?	14
8. Could these spots be readily removed without leaving a ring?	2
9. Were dirt and stains removed by dry cleaning?	0
10. Did you notice any glazing of the uniform as a result of commercial dry cleaning and pressing?	0
11. Have you notice any fading? If so, where?	0
12. Have you noticed any signs of pilling?	2
13. Have you noticed any signs of abrasion or wear exclusive of pilling? Where?	0
14. Have you noticed any shifting, pulling or puckering of seams?	1
15. Have you noticed any objectionable static (clinging)?	5

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TABLE I

ion of Data from Questionnaires

	A - B		A - C		A - D		B - C		B - D		C - D	
	30	29	24	23	22	22	24	25	18	20	24	24
	0	25	5	11	5	12	12	5	12	0	20	3
	0	16	0	3	1	10	1	1	6	0	14	3
?	0	16	2	6	2	7	1	2	5	0	5	3
	0	11	0	0	2	1	0	0	1	0	2	0
r several	3	7	1	4	1	0	0	0	1	3	2	2
	7	0	2	1	1	1	1	5	1	6	1	2
	14	2	3	0	0	0	1	9	0	3	1	2
	2	1	2	0	1	0	0	1	0	0	0	1
	0	1	2	1	0	0	0	0	0	1	0	3
d pressing?	0	0	0	0	0	0	0	0	0	0	0	1
	0	1	0	0	0	0	0	0	0	0	0	0
	2	2	0	0	0	0	4	0	1	0	1	0
	0	2	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	1	0	0	1	0	1
	5	0	0	0	0	0	1	3	1	1	0	1

* These data were compiled to give the preferences expressed for one fabric over the other, and do not represent direct answers to the questions.

Comparisons should be made only between results obtained for fabrics of the same group, since these data indicate the participant's reactions to certain fabric properties only in direct comparison to the companion fabric within his group. For example, while Fabric A showed a marked superiority to Fabric B (Group A-B) in regard to spotting or staining (question no. 7), it was little better than Fabric C (Group A-C) and no better than Fabric D (Group A-D) in this respect.

Table II

Acceptability Indexes of Fabrics Evaluated

Question (Ranked in order of importance)	Order of preference	Weight of question	Adjusted preference points				Acceptability Number			
(a)	(b)	(c)	(d)				(e)			
			A	B	C	D	A	B	C	D
1	B - C - D - A	8	1	4	3	2	8	32	24	16
2	(B - C) - D - A	7	1	3	3	2	7	21	21	14
4	B - A	7	2	3	2 1/2	2 1/2	14	21	17 1/2	17 1/2
7*	A - C - D - B	7	4	1	3	2	28	7	21	14
6	(A - C - D) - B	6	2	1	2	2	12	6	12	12
3	(B - C - D) - A	6	1	2	2	2	6	12	12	12
12	B - C	5	2 1/2	3	2	2 1/2	12 1/2	15	10	12 1/2
9	D - C	5	2 1/2	2 1/2	2	3	12 1/2	12 1/2	10	15
15	A - B	5	3	2	2 1/2	2 1/2	15	10	12 1/2	12 1/2
Acceptability Index							115	136 1/2	140	125 1/2

* Note: Anomalous results obtained for this question.

Table V presents the data regarding "Comfortable" and "Uncomfortable" wearings and frequency of cleanings and pressings.

The data from Table III, when analyzed, show that B is significantly more comfortable than A, C is significantly more comfortable than B, and D is significantly more comfortable than A. No significant differences were noted between the comfort of C and D, between B and D, or between A and C. It is interesting to note that the personnel in Groups which did not have an all wool uniform were much less likely to comment on relative comfort of either uniform. For example Group I personnel rated fabric B "Uncomfortable" on 48 occasions out of 247 wearings, while Group V personnel rated the same fabric "Uncomfortable" in only two cases. There is no apparent explanation for this, but it seems possible that the relative discomfort of the all wool fabric made the participants "comfort conscious" so that they were more prone to comment on the comfort of both the test fabrics. The "comfort " reactions were inconsistent, but indicate that the comfort level of the test fabrics was at least equal to that of the wool fabric.

Table III

	A - B		A - C		A - D		B - C		B - D		C - D	
Wearings	231	247	190	152	140	174	179	193	154	161	217	184
Uncomfortable wearings	70	48	44	27	26	9	17	9	2	2	4	7
% Uncomfortable wearings	30	15	23	18	19	5	9	5	1	1	2	4
Drycleanings	38	43	30	32	21	28	30	32	26	28	38	40
Pressings	39	45	32	32	21	28	32	32	26	30	38	40

All evaluations which attempt to tabulate human reactions, especially the complex ones related to wearing apparel, are subject to wide differences of opinion. However, as the program was conducted under controlled conditions, and as one would expect the direct comparisons made to give valid results, it will be assumed that the differences are real and are attributable to specific fabric characteristics.

The physical properties of the fabrics are given in Table VI. Examination of these fails to indicate any differences which would markedly affect the reactions of the participants. The weights are normal for summer garments and substantially the same except for fabric B. The air permeability variations of the magnitude shown might well occur from roll to roll of the same fabrics.

Since the fabrics were worn principally in the performance of indoor duties, the variation in air permeability alone can probably be discounted to a large extent as a possible source of variation in comfort reaction.

One of the remaining obvious factors which would affect comfort is the ability of the materials to transmit moisture. This property was measured under one set of conditions to provide a basis for comparison. The method described by Kanagy and Vickers (1) was modified by replacing the desiccant in the aluminum cell with saturated loose cotton fiber covered with filter paper in such a manner that the test fabric was held in constant contact with a moist surface. 1/ The prepared cups were weighed and placed on a rack in a stream of moving air having a velocity which corresponds to the air motion of a gentle breeze, approximately 3.9 miles per hour. The velocity of air was checked frequently with a velometer at all points around the rack to insure a relatively constant flow condition. The temperature was maintained at 70° F. and the relative humidity at 65% R.H. The air permeability and the moisture transmission rate was determined for both single and double thicknesses of fabrics. The test results are presented in Table IV. The lack of correlation between moisture transmission and air permeability is not surprising and in view of Kanagy's findings would have been expected. His determinations of the moisture transmission rates of nylon and glass fabrics having equal air permeabilities showed that the glass fabric, although more hydrophobic, had higher transmission rates than the nylon fabric. It appears that the popular conception that hydrophobic synthetic fibers produce "hot" fabrics with poor moisture transmission properties may be erroneous, at least under moving air conditions. Several months ago a number of fabrics were investigated by the Materials Laboratory for moisture transmission rates under static air conditions. The data are presented in Table V. In this test the fabrics were placed over the mouths of aluminum cups (500 cc capacity) which contained 75 cc of water. The cups were placed in a $CaCl_2$ desiccator, and were then removed and weighed periodically. A singular lack of correlation between fiber content or air permeability and moisture transmission rate will be noted for these fabrics. It is certain that this whole subject will bear more thorough investigation.

- -

1/ This apparatus consists of an aluminum cup with a flange bent in such a way that a raised rim is formed at the edge of the cup, upon which the fabric fits tightly. The cup is filled with saturated absorbent cotton fibers which are covered with a paper blotter cut to just fit the cup. A piece of fabric larger than the cup is placed over the cup and pressed into place with a metal template machined to have one surface the same diameter as the cup. Molten wax is poured around the groove formed by the template and the flange. After the wax hardens the template is removed, leaving an area of 25 cm^2 of the fabric exposed.

Table IV

Moisture Transmission and Air Permeability Rates of the Fabrics Evaluated

Fabric	Air Permeability ($ft^3/min/ft^2$)		Moisture Transmission* ($gm/100cm^2/24$ hrs)	
	Single thickness	Double thickness	Single thickness	Double thickness
A	53	22	29	24
B	73	38	50	42
C	101	54	42	41
D	62	31	50	57

* These figures are an approximation of moisture transmission rates 6 hours after the tests began. The complete data are presented graphically in Figure 2, Page 10.

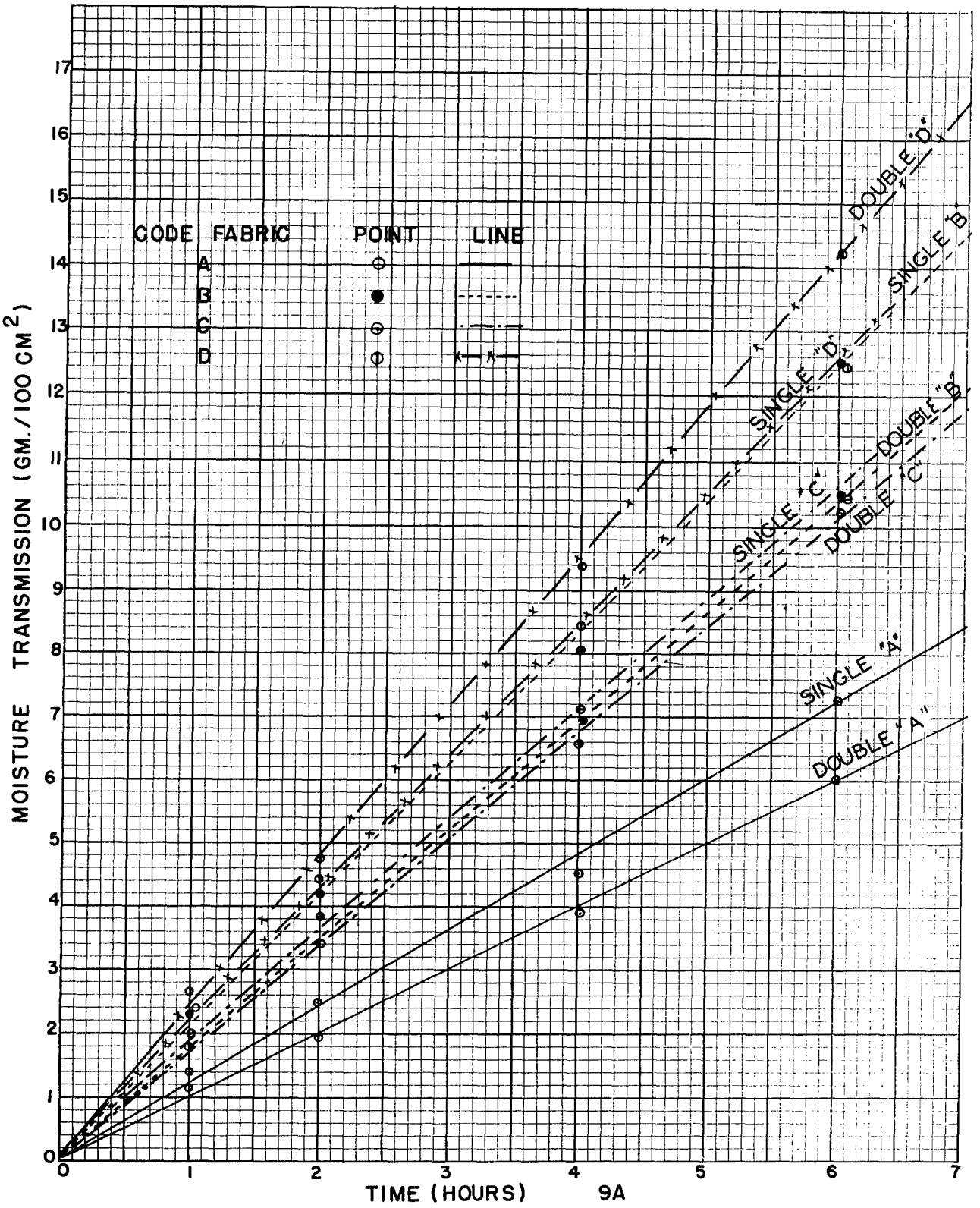

FIG. 2 MOISTURE TRANSMISSION AND AIR PERMEABILITY RATES OF THE FABRICS EVALUATED

Table V

Moisture Vapor Transmission Properties of Certain Fabrics

Fabric Composition	Moisture Vapor Transmission Rate ($gms/100in^2/24$ hrs)	Air Permeability ($ft^3/min/ft^2$)	Weight (oz/yd^2)
50% viscose, 50% acetate warp and filling	20.7	22.6	4.89
50% viscose, 50% acetate warp; 100% acetate filling	20.2	35.3	3.40
100% filament acetate warp; 25% viscose, 75% acetate filling	20.3	29.2	4.21
50% viscose, 50% acetate warp and filling	20.5	24.8	3.96
100% worsted (wool) warp and filling	21.4	22.0	4.12
100% worsted (wool) warp and filling	21.8	16.2	3.96
60% viscose, 40% wool warp and filling	18.7	63.3	3.65
1 end filament acetate, 1 end 50% acetate, 50% viscose warp; 50% acetate, 50% viscose filling	19.7	61.9	3.77
1 yarn filament acetate twisted with 1 yarn 50% acetate, 50% viscose warp; 50% acetate, 50% viscose filling	20.4	61.0	3.99
50% viscose, 50% acetate warp and filling	20.1	80.6	3.82
1 end filament acetate, 1 end 50% acetate, 50% viscose warp; 2 picks filament acetate and 2 picks 50% acetate, 50% viscose filling	21.5	41.0	4.18
100% filament acetate	20.3	18.8	4.22

The problem of measuring wrinkle resistance is one which has been studied by many investigators and it is beyond the scope of this report to discuss the details of the various methods used. The Monsanto Wrinkle-Recovery Tester is considered one of the better devices for measuring this property. The work done by Gantz (2), using this device, indicates that polyester fiber fabrics have superior wrinkle-resistance to wool fabrics at both 70° F. and 65% R.H. and 70° F. and 95% R.H. and especially at the higher humidity.

Preliminary data obtained by the Materials Laboratory show a similar superiority. The data have not been checked sufficiently to report at this time, but at 70° F. and 65% R.H. general agreement with Gantz's figures has been obtained. The participants' reports on wrinkle-resistance showed a preference which correlates with Gantz's evaluation of mono-fiber fabrics. He rates such fabrics in the following order of wrinkle-resistance: (1) polyester fabric (2) wool fabric (3) viscose rayon fabric. The wear-test participants, as previously shown, (Table II) rated the test fabrics in a similar order: (1) all polyester fabric (2) wool-polyester fabric (3) rayon-polyester fabric. Beste and Hoffman's investigations of fiber resilience as measured by recovery from tensile stresses (3) indicate a slightly superior performance for the wools tested compared to the polyester fibers tested. These findings are not necessarily contradictory to Gantz's measurements since a perfect correlation between fiber and fabric resilience has not yet been established.

III. Miscellaneous Data:

It is impossible to predetermine all of the factors that will exist in an investigation of this type. In the portion of the questionnaire allowed for "Remarks" several unexpected qualities of the 100% Dacron fabric were brought to attention.

The Dacron fabric exhibited an affinity for foreign matter that seriously detracted from its value in a light colored fabric such as used in this test. This affinity is probably largely attributable to the positive static charge almost always present in this fabric. The attraction of such a charge would no doubt make it difficult to keep the fabric clean. The presence of static on the all-Dacron fabric appears to be a serious deficiency.

Also, the extremely hard surface of the Dacron seemed to abrade upholstery, seat covers, and other commonly encountered surfaces in such a manner as to increase the possibility of soiling the fabric.

Several participants remarked that the fabric was very susceptable to burns from cigarette ashes. This was undoubtedly due to the thermoplastic nature of the fiber.

Table VI

Some Physical Properties of the Test Fabrics

Fabric number	1	2	3	4
Weight (oz/yd^2)	6.35	5.63	6.75	6.3
Texture	52 x 51	65 x 52	55 x 46	60 x 50
Yarn ply	2 x 2	2 x 2	2 x 2	2 x 2
Breaking strength (grab)(lbs/in)	62 x 63	158 x 120	119 x 98	95 x 77
Color fastness				
Light (20 Hours)	good	good	good	fair
Light (40 Hours)	good	fair	fair	poor (38 hours)
Drycleaning	good	good	good	good
Laundering ($100^{o}F.$)	good	good	good	good
Perspiration	good	good	good	good
Crocking	good	good	good	good
Abrasion resistance				
Flex abrasion	184	755	387	922
Diaphragm abrasion	287	3465	351	770
Air permeability ($ft^3/min/ft^2$) at 1/2" water pressure differential	53	73	101	62

The participants after two to four wearings found it necessary to have the garment cleaned and consequently pressed because of the garment's soiled condition. From these facts, it may be concluded that the claims of the manufacturer of Dacron that the fiber will produce garments which are easier to maintain due to their superior crease retention, were neither proved nor disproved in this evaluation.

IV. Conclusions:

A. The test participants reported a higher percentage of uncomfortable wearings for the all wool than for any of the experimental fabrics. Table VII tabulates these results.

Table VII

	No. of Wearings	No. of Uncomfortables	Percentage of Uncomfortables
A)	561	140	25%
B)	580	67	11.5
C)	562	40	7.1
D)	519	18	3.5

This table further substantiates the merit of rating the fabrics D, C, B, and A as the order of comfort.

B. The "Acceptability Indexes" of the fabrics indicate a general performance superiority for the experimental fabrics over the control fabrics.

C. While the all Dacron fabric had a high "Acceptability Index" certain properties were discovered which mitigate against its use, i.e., susceptability to melting by tobacco ashes, and development of static electricity.

V. Recommendations:

A. Based on the results reported herein fabrics C and D (55% Dacron - 45% Wool and 50% Dacron - 50% rayon) have been adopted for USAF summer uniforms, and it is recommended that their performance in general use be followed carefully.

B. It is recommended that the performance of the test uniforms be observed during this and following seasons to obtain further data especially in regard to durability.

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APPENDIX I

Test for Significance of Data

The following formulae were used in determining statistical significance:

$$\sigma_{P_i - P_j} = \sqrt{\frac{P_i(1-P_i)}{N_i} + \frac{P_j(1-P_j)}{N_j}}$$

$$t = \frac{P_i - P_j}{\sigma_{P_i - P_j}}$$

P Estimated Probability of a Favorable Report

i & j Subscribts to designate fabrics

N Number of reports on that fabric

when t is equal to or greater than 1.65 the difference is considered significant.